Tribology
(Friction, Wear, Lubrication and Bearing)

TRIBOLOGY

(FRICTION, WEAR, LUBRICATION AND BEARING)

By

Krishan Kant Sharma

Astt. Professor, Department of Mechanical Engineering

Galaxy Global Group of Institutions

Ambala, Haryana

UNIVERSITY SCIENCE PRESS

(An Imprint of Laxmi Publications Pvt. Ltd.)

BANGALORE ● CHENNAI ● COCHIN ● GUWAHATI ● HYDERABAD
JALANDHAR ● KOLKATA ● LUCKNOW ● MUMBAI ● RANCHI
NEW DELHI ● BOSTON, USA

Published by :

UNIVERSITY SCIENCE PRESS

(*An Imprint of Laxmi Publications Pvt. Ltd.*)

113, Golden House, Darya Ganj,
New Delhi-110 002

Phone : 011-43 53 25 00
Fax : 011-43 53 25 28

www.laxmipublications.com
info@laxmipublications.com

Price : ₹ **125.00** *Only.* *First Edition :* 2013

OFFICES

✆ **Bangalore**	080-26 75 69 30	✆ **Chennai**	044-24 34 47 26
✆ **Cochin**	0484-237 70 04, 405 13 03	✆ **Guwahati**	0361-251 38 81
✆ **Hyderabad**	040-24 65 23 33	✆ **Jalandhar**	0181-222 12 72
✆ **Kolkata**	033-22 27 43 84	✆ **Lucknow**	0522-220 99 16
✆ **Mumbai**	022-24 91 54 15	✆ **Ranchi**	0651-220 44 64

UTR–9692–125–TRIBOLOGY–SHA **C—**

Typeset at : Sukuvisa Enterprises, New Delhi. *Printed at* :

Preface

I am glad to present the book entitled, 'Tribology (friction, wear, lubrication and bearing)' for the engineering students of mechanical, civil, automobile and aeronautical. The course contents have been planned in such a way that the general requirements of all engineers, researchers and students are taken care of. Because there were problems in recommending any single textbook which containing all the units according to University Syllabus. Existing textbooks were either too specialized or too literal. Many books provided exhaustive reviews of friction, lubrication, bearing and wear data while others provided detailed description of the lubrication and wear problems occurring in machinery.

In this book various concepts explained in the simplest possible terms with supporting illustrations and simple diagrams to understand the working of that part/topic. The book is written in a simple and easy-to-follow language, so that even an average students can easily grasp the subject by self-study.

At the end of chapters many questions and unsolved problems are given to solve. Extra diagrams and last year's University Question Papers have also been included where it was found that the readability of the original text could be improved. The subject matter of the book is also relevant to mechanical and materials engineering, applied chemistry and physics courses.

I express my appreciation and gratefulness to my parents, publisher, colleagues, friend and students who encouraged me to write this book.

—Author

CONTENTS

Chapter 1

TRIBOLOGY

1.1 INTRODUCTION

Tribology, the concept which focuses on friction, wear and lubrication of interacting surfaces in relative motion. Tribology is based on that when two bodies moving, sliding on each other then friction occurs Fig. 1.1. Tribology in a traditional form has been in existence a well studied examples of how early civilizations developed in bearings and low friction surfaces. The study of tribology the basic laws of friction, such as the proportionality between normal force and limiting friction force. Understanding of friction and wear in the surface of the bodies, to explain the underlying mechanisms. The relatively low priority of tribology concept that nobody really bothered what would happen when motion between the spheres and surfaces was in a downward direction. Tribology is the field of science which studies the improved friction control. The work of Reynolds initiated countless research efforts aimed at parts of improving the interaction between two contacting surfaces. As a result journal bearings are now designed to high level of sophistication. Wear and the fundamentals effect of friction are far more complex problems, the experimental investigation based on advanced instrumentation scanning electron microscopy and atomic forces microscopy. Tribology is according to the Fig. 1.1 shows is the study of the wear, friction and lubrication.

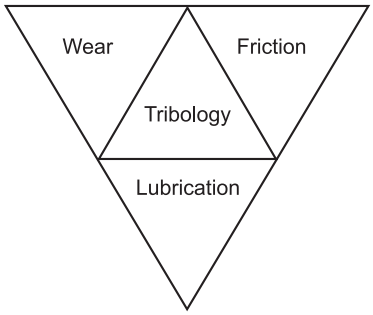


Fig. 1.1

In the field of Tribology affects our lives to a much greater degree than is commonly realized field of science, most of the knowledge being gained after the Second World War. In comparison many basic engineering subjects, *e.g.*, material science, thermodynamics, mechanics and plasticity, are relatively old and well established. Tribology is an imperfect subject to some controversy which has impeded the diffusion. We can say that Tribology is the study of friction, wear, and lubrication.

1.2 MEANING OF TRIBOLOGY

The meaning of Tribology based upon the principal causes of wear, friction and lubrication. **'Tribology'** is derived from the Greek word **'tribos'** meaning rubbing or sliding surfaces. On the two surfaces when one surface slides over the another surface. The word 'tribology' has gained gradual acceptance, is relatively new, its meaning is still unclear community and numorous comparisons with tribes or tribolites tend to persist. Wear is the major cause of material wastage and loss of mechanical various stages of performance and any reduction in wear can result in considerable savings. Friction is a principal cause of wear and energy dissipation. Considerable savings can be made by improved friction control surfaces one third of the world's energy resources is needed to overcome friction in one form or another. Lubrication is an effective means of controlling wear, function of lubricant and reducing friction. Tribology which applies an operational analysis to overcomes problems of great economic significance such as reliability, maintenance of technical equipment ranging from household appliances. The majority of problems accounted in the field of tribological. Figure 1.2 shows the study of the wear friction and lubrication in various field of engineering.

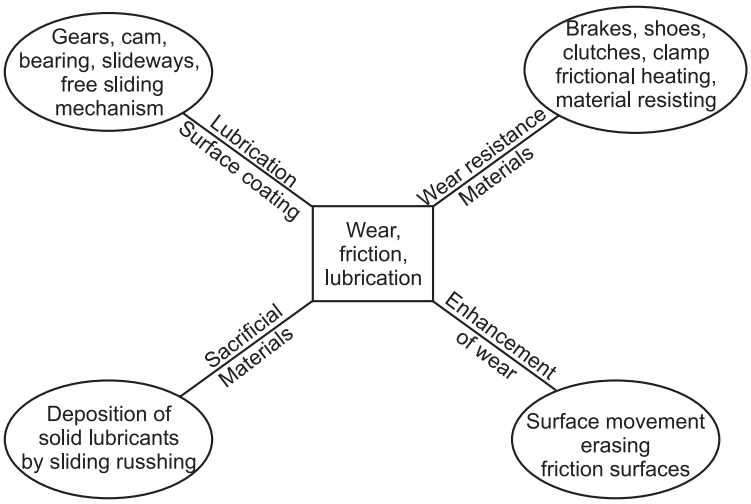


Fig. 1.2

In our Daily lives there are so many examples like as our human body also contains interacting surfaces, *e.g.*, human joints, which are subjected to lubrication and wear. Deposition of solid lubricants by sliding the lubrication of human joints is still far from fully understood. Tribology affects our lives much greater degree than is commonly realized. For example, the deliberate control of friction and wear was first promoted, human beings and naturally animals were instinctively modifying friction and wear as it affected their own bodies. Tribology is the contact mechanism of the lubricant Additives, construction, mechanical and chemistry and Environmental Engineering. It is common knowledge that the engine becomes noisey and vibration as a response to stress or damage. It has only recently been discovered that damage on the parts of the engines due to the wear and friction and less uses of the lubricants between both the surfaces.

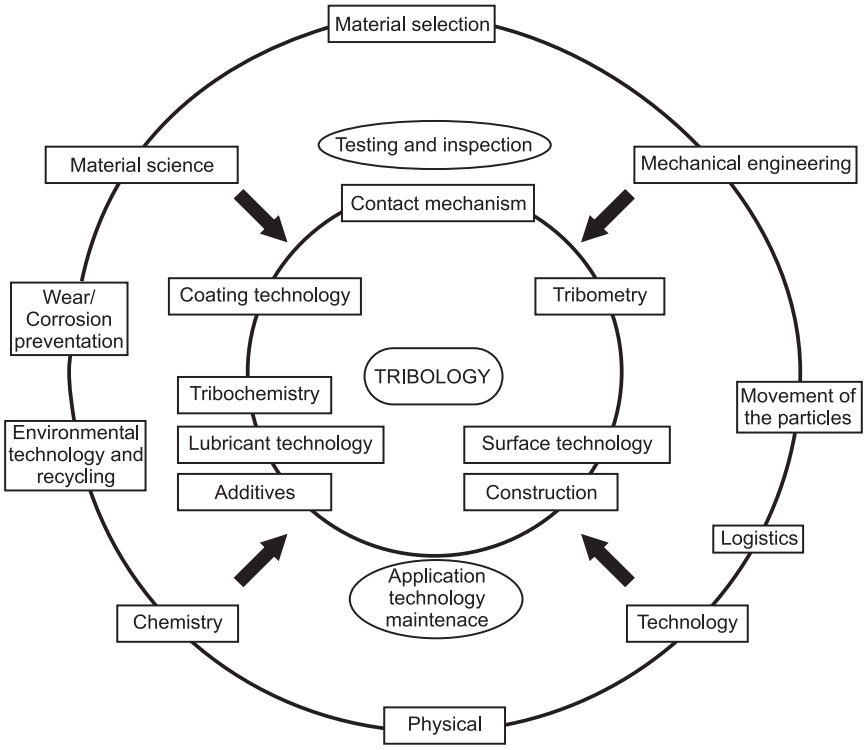


Fig. 1.3: Interacting surfaces

In Tribology why 'the interacting surfaces in relative motion', (which essentially means moving, rolling, sliding, normal approach or separation of surfaces), are important to our economy? How and why they affect our standard of living? Surface interaction of particles dictates or controls the functioning of practically every device developed by man in nature. Everything that nature makes wears out, almost always as a result of relative motion between surfaces. An analysis of machine breakdowns, parts missalign show that in the majority of cases failures and stoppages are associated with interacting moving parts such as rollers, gears, bearings, couplings, sealings, cams, clutches, etc. As shown in Fig. 1.4 the Tribocycle is studied the manufacturing systems, design the part, new technology and the selection of the material and surface technologies.

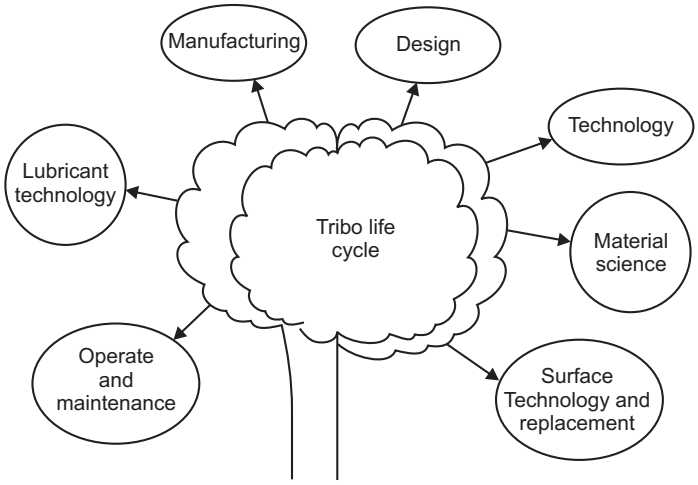


Fig. 1.4: Tribo life cycle

To study of the best method of wear, friction, lubrication so that we reduces the power consumption and design out maintenance.

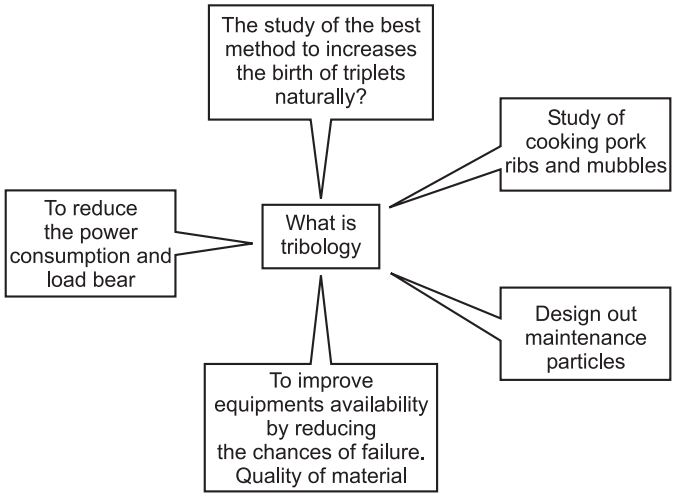


Fig. 1.5

To improve equipments availability by reducing the chances of failure, tribology comprises the study of:

- the characteristics of films of intervening surface material between contacting bodies. Design of maintenance.
- the consequences of either film material failure or absence of a film which are usually manifested by severe friction and wear so that improving equipments' ability.

Between surfaces the film formation any pair of sliding objects is a natural phenomenon which can occur with or without human intervention. Film formation might be the fundamental mechanism preventing over extremely high shear rates at the interface between two rigid sliding objects or particles.

Lubrication

Lubrication is the process, or technique employed to reduce or minimize wear of one or both surfaces in close proximity, and moving relative to each another, by interposing a substance called *LUBRICANT*, between the surfaces to carry the load (pressure generated) between the opposing surfaces. The interposed lubricant film can be a solid, (*e.g.*, graphite, MoS_2) a solid/liquid lubricant dispersion, a liquid, a liquid-liquid dispersion (greases) or exceptionally a gas.

According to Fig. 1.6, when the two bodies surfaces contacting and rubbing then the friction and wear occurs so avoid wear on the surface we generally use lubricants. These layers of material separate contacting solid surfaces, bodies and are usually very thin and often difficult to observe. In general, the thicknesses of these films range from **1–100 [μm]**, although thinner or thicker films. Knowledge of layers that is related to enhancing or diagnosing the effectiveness of these films in preventing damage, film in solid contacts is commonly known as **'lubrication'.** To avoid wear on the surfaces generally uses the lubricants which known as the lubrication between the surfaces. For example, gaseous film is suitable for low contact stress while solid films are usually applied to slow sliding speed contacts. Detailed analysis of gaseous or liquid films is usually termed **'hydrodynamic lubrication'** while lubrication by solids is termed

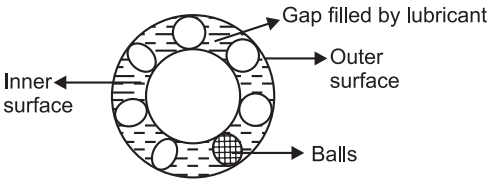


Fig. 1.6

'solid lubrication'. In the Fig. 1.7 shown the lubricant between the material (A) and material (B) when the bonded elastomers are forced by the applied load. Lubrication is the layer which is filling the gap between the two particles A and B to reduces the friction and wear.

According to Fig. 1.7 there are two surfaces and the gap between them, when load applied and force is also there so that friction and wear occurs to avoid wear a thin film layer is obtained known as lubrication.

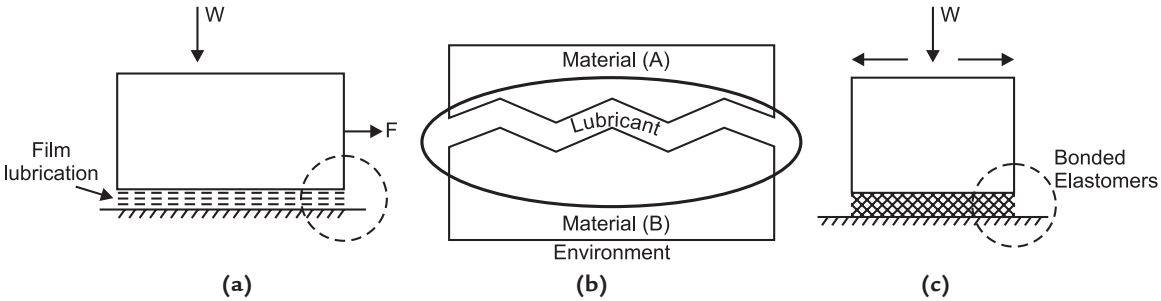


Fig. 1.7

In the absence of film, the only reliable means of ensuring relative movement between surfaces is to maintain, by external force fields, a small distance of separation between the opposing surfaces. When the Block moves on the surfaces and the load and force W is applied then wear occurs. So lubricants provided for better performances. A form of lubrication that operates by the same principle, *i.e.*, forcible separation of the contacting bodies involving an external energy source, during movement is **'hydrostatic lubrication'** where liquid or gaseous lubricant is forced into the space between contacting bodies. Liquid lubrication is a technological nuisance since filters, pumps and cooling equipments are required to maintain the performance of the lubricant over a period of time. To avoid the noisey and vibration between both the surfaces we generally provided the lubricants between them. Liquid lubricants are the loss of load carrying capacity at high temperature and degradation in service. The performance of the lubricant depends on its composition and its physical and chemical characteristics, of the surfaces when processes occurs on the surfaces of the material. Prediction methods for liquid or gaseous films involve at the elementary level of boundary, hydrodynamic, hydrostatic and elastohydrodynamic lubrication. For more sophisticated analyses **'computational methods'** must be used.

Wear

Wear is the erosion of material from a solid surface by the action of another surface. It is related to surface interactions and more specifically the removal of material from a surface as a result of mechanical action. The need for mechanical action, in the form of contact due to relative motion, is an important distinction between mechanical wear and other processes with similar outcomes. The consequence of film failure is severe wear. Wear in these circumstances is the result of adhesion between contacting bodies and is termed **'adhesive wear'.** Intervening films are partially effective then milder forms of wear occur and these are often initiated by fatigue processes due to repetitive stresses under either sliding or rolling. These milder forms of wear can therefore be termed **'fatigue wear'.** The film material consists of hard particles or merely flows against one body to another without providing support then a form of wear, which sometimes can be very rapid, known as **'abrasive wear'** occurs.

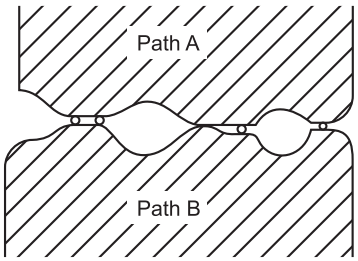
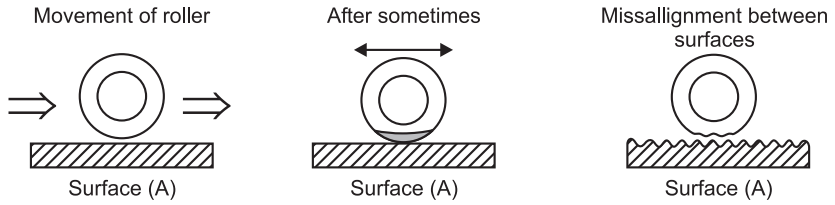


Fig. 1.8



Two other associated forms of wear are erosion wear and cavitation wear which is caused by fast flowing liquids. Generally these forms of wear are **'erosive wear'** (due to impacting particles) and **'cavitation wear'** which is caused by/fast flowing liquids. In practical situations the film material is formed by chemical attack of either contacting body and while this may provide some lubrication, significant wear is inevitable. This form of wear is known as **'corrosive wear'** and when atmospheric oxygen is the corroding agent, then **'oxidative wear'** occur. When the amplitude of movement between contacting bodies is restricted a few micrometres, the film material is trapped within the contact and may eventually become destructive. Under these conditions **'fretting wear'.** Any interaction between solid bodies will cause wear. Examples are **'impact wear'** caused by impact between two solids, **'melting wear'** occurring when the contact loads and speeds are sufficiently high to allow for the surface layers of the solid surfaces to melt, and **'diffusive wear'** occurring at high interface temperatures. This dependence of wear form on various operating conditions can be summarized in a flow chart.

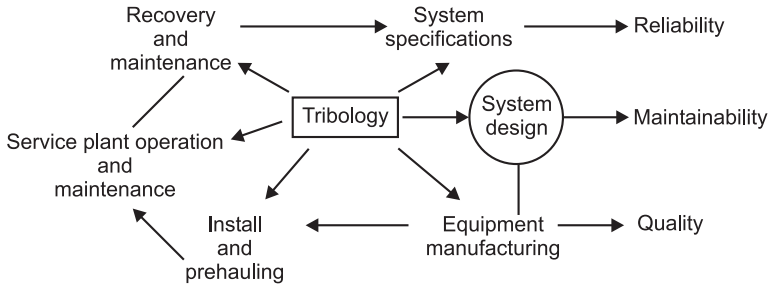


Fig. 1.9: Role of Tribology in different espects

1.3 LEARNING TRIBOLOGY

Tribology is ultimately an applied knowledge in, many topics like as wear, lubrication, bearings, friction and their classifications. It is not a science by itself although research is done in several different stages to understand the fundamental aspects of tribology. It has the effect of perpetuating (and even splintering) the field along disciplinary lines. Tribology is the system design for the Better Quality, higher performances, Realiability, Installation and system specifications. Tribology is a simple and straightforward art. In academic preparation for designing products, most students in mechanical engineering (the seat of most design instruction) have taken courses in such topics as:

(*a*) Fluid mechanics, fluid machines

(*b*) Elasticity (described as solid mechanics), Ductile, plasticity

(*c*) Materials science (survey of atomic structure and the physics of solids)

(*d*) Dynamics (mechanical mostly)

(*e*) Heat transfer

(*f*) Methods of mechanical design, material design.

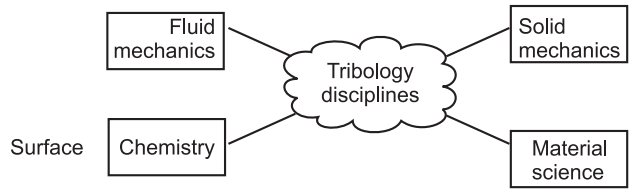


Fig. 1.10: Role of Tribology in mechanical engineering

(*g*) Plasticity and elasticity

(*h*) Visco-elasticity

(*i*) Contact mechanics, surface finish

(*j*) The full range of mechanical properties of monolithic materials, composite materials, and layered structures (coatings, etc.), especially fracture toughness, creep, fatigue (elastic and low cycle)

(*k*) Surface chemistry, oxidation, adhesion, adsorption

(*l*) Surface-making processes

(*m*) Statistical surface topographical characterization methods

(*n*) Lubricant chemistry, solid mechanics

(*o*) and several more.

These are useful tools indeed, but hardly enough to solve a wide range of problems in friction and wear.

1.4 THE SEVERAL DISCIPLINES IN THE FIELD OF TRIBOLOGY

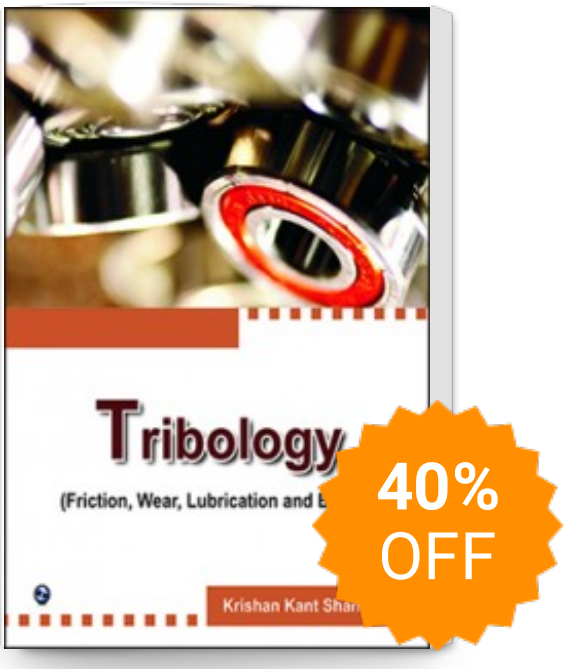
In the study of the tribological system of material engineering will have different set of tools which are used to justify the concept of Tribology and beware all the mechanics.

1. Solid Mechanics: Focus is on the mathematics of contact stresses and surface temperatures due to sliding. friction and wear rates of selected mechanical devices that are based on very simple physical tribological mechanisms. Which are related to the solid mechanism.

2. Material Science: The atomic and microscale mechanisms whereby solid surface degradation or alteration occurs during sliding work in this area is usually presented in the form of micrographs, as well as energy spectra for electrons and X-rays from worn surfaces. In the material science studied based on metals and alloys. Firstly, the limit of knowledge in the materials aspects of tribology has not yet been found. Second material scientists (engineers, physicists) rarely have a broad perspective of practical tribology. (Material engineers often prefer to be identified as experts in wear rather than as tribologists.)

3. Applied Surface Chemistry: The reactivity between lubricants and solid surfaces. Work in this area progresses largely by orderly chemical alteration of bulk lubricants and testing of the lubricants with bench testers. The major deficiency in this branch of tribology is the paucity of

Tribology (Friction, Wear, Lubrication And Bearing) By Krishan Kant Sharma



Publisher : Laxmi Publications ISBN : 9789381159613

Author : Krishan Kant Sharma